American POTATO JOURNAL

Volume 27 | November, 1950 | Number 11

CONTENTS

Stabilization and Intensification of Red Skin Color in Red McClure Potatoes by Use of the Sodium Salt of 2-4 Dichlorophenoxyacetic Acid—*Jess L. Fults, L. A. Schaal, Nellie Landblom and Merle G. Payne* 377

Air and Soil Temperatures in Potato Fields, Kern County, California, During Spring and Early Summer—*O. A. Lorenz* 396

Storage of Potato Seeds—*F. J. Stevenson and W. C. Edmundson* 408

Sectional Notes 411

Program of the Annual Meeting of the Potato Association of America 413

Official Organ of

THE POTATO ASSOCIATION OF AMERICA

NEW BRUNSWICK, NEW JERSEY


"biggest and best crop in years"
Increase your Potato yield with protection measures against fungus disease the Mallinckrodt way. In ordering your Corrosive Sublimate (Bichloride of Mercury), Calomel, or Mercury Oxide Yellow Technical, be sure of highest quality by specifying MALLINCKRODT-MERCURIALS.

American Potato Journal

PUBLISHED BY

THE POTATO ASSOCIATION OF AMERICA

NEW BRUNSWICK, N. J.

$2.00 per year, United States and Canada, $2.50 per year elsewhere.

Entered as second class matter at New Brunswick, N. J., March 14, 1942, under Act of March 3, 1879.
Accepted for mailing at special rate of postage provided for in section 412, Act of February 28, 1925, authorized on March 14, 1928.

STABILIZATION AND INTENSIFICATION OF RED SKIN COLOR IN RED McCLURE POTATOES BY USE OF THE SODIUM SALT OF 2,4-DICHLORO-PHENOXYACETIC ACID[1]

JESS L. FULTS, L. A. SCHAAL, NELLIE LANDBLOM and MERLE G. PAYNE[2,3]
Agricultural Experiment Station, Colorado A. and M. College
Fort Collins, Colo.

(Accepted for publication March 29, 1950)

The Red McClure variety (Dark Red Perfect Peachblow) was introduced to the San Luis Valley of southern Colorado by Earnest Hatfield about 1910. Hatfield brought what was called a "peach blow potato" from Penn-

[1] Published with the approval of the Director, Colorado Agricultural Experiment Station, as Scientific Series Paper No. 323.

[2] Botanist, Colorado Agricultural Experiment Station; Pathologist, Bureau of Plant Industry, Soils and Agricultural Engineering, U. S. Department of Agriculture; Research Statistician, Colorado Agricultural Experiment Station; and Assistant Chemist, Colorado Agricultural Experiment Station, respectively.

[3] The authors wish particularly to acknowledge the assistance of Mr. Frank McGee, who cared for the planting, cultivation and harvesting of the crop, Mr. Richard Garber and Mrs. Ruth J. Hay, who assisted in the field and laboratory, the San Luis Valley Potato Board of Control for financial assistance, and Mr. Clifford Edmundson for planting, cultivation and harvest at the U. S. D. A. Potato Station at Greeley, Colorado.

[4] Numbers in parentheses refer to literature cited.

sylvania. Later this variety was produced at Carbondale, Colorado, and then returned to the San Luis Valley by Thomas McClure from which the variety got its name of Red McClure. The skin-color of this strain was a light red. In 1933 the first dark red McClures were selected in the divide country of Colorado and then brought to the valley for production. (8)[4]

Red McClures often have a poor skin-color under certain growing conditions, *i. e.*, long growing season. This seems to be particularly true of those tubers which are allowed to remain in the soil after the peak of the growing season is reached (12). In addition, as has been indicated by Sparks (28), some of the original normally light-red McClures are still being used for planting. Whatever the cause or causes of the poor skin-color of Red McClures in the past, it has often meant a substantial loss to the growers. Sparks (28) has cited specific instances during the 1941-1942 season of a market differential of 11 cents per 100 pounds on carlot shipments and 19 cents per 100 pounds on truck shipments in favor of dark red-skinned McClures compared with light red. Disadvantage to the grower was illustrated during the marketing of the 1948 crop when buyers and commission men used "poor color" as a means of adjusting prices to their advantage (12). For these reasons and others, the growers in the San Luis Valley have been interested in any reasonable, cheap practice that would stabilize and improve the red skin-color of their product. Accordingly during both the 1948 and 1949 seasons, the San Luis Valley Potato Improvement Association, in cooperation with the Colorado Agricultural Experiment Station, has financed a study of the effects of synthetic plant hormones on Red McClure potatoes.

Objectives of Hormone Experiments

The immediate objective of the 1949 trials has been to investigate the effects of the sodium salt of 2,4-D on red skin-color and yields. Other objectives have been to determine 2,4-D treatment effects on vitamin C content, specific gravity, anthocyanin skin pigments, skin thickness, sprouting during late storage, stands and yields of the next succeeding crop and market value of hormone-treated, dark red-skinned potatoes. Only data on skin-color and yields will be presented in this report.

Review of Literature

Use of Minor Elements

The exploration of the use of synthetic plant hormones as a possible way to stabilize and increase the red skin-color of Red McClures is not the first attempt to find a solution to the problem. The first published reports were the simultaneous ones of Sparks (28) and of McLean, Sparks and Binkley (17). As a result of greenhouse study and of a series of field tests in 1941 at the San Luis Valley demonstration farm near Monta Vista, Colorado, significant in-

creases in red skin-color, yield and skin-thickness were obtained by treating the soil at planting time with 25 pounds per acre each of copper, iron and manganese sulphate. Further work by Kunkel (14) during the 1946, 1947, and 1948 seasons, using the same chemicals, at the same rates as those of Sparks on the same farm, has failed to confirm the work of either Sparks (28) or McLean *et al* (17). In the report by Kunkel (13) results for effects of minor elements on skin-color, yields, cooking quality (specific gravity) and grade have been non-significant.

Use of Synthetic Plant Hormones

Most workers who have applied synthetic plant hormones to potatoes have had as their main objective improving potato quality, increasing yields, weed control, or inhibition of sprouting in storage.

Improving Potato Quality

One of the first reports of the use of a synthetic plant hormone to increase the red skin-color of potatoes was that of Fults and Schaal (9), who worked with Bliss Triumphs. The compounds used were the sodium and the ammonium salts and the butyl ester of 2,4-D applied to the soil as a side dressing at a rate of 20 pounds per acre when the tubers were one-third grown. All compounds gave increased red color with no reduction in yield, and no change in flesh-color. Ellis (6) working in Indiana has independently demonstrated increased red skin-color in Triumphs due to treatment with the sodium salt of 2,4-D applied at rates of 0.52 to 2.1 pounds per acre.

Prince and Blood (19) have studied the effects of spraying growing plants with the butyl ester of 2,4-D on the specific gravity of the Irish Cobbler, Green Mountain, Sebago, Houma, Chippewa and Katahdin varieties of potato. All varieties increased in specific gravity which suggested that the treatment offers possibilities of improving potato quality.

Increasing Potato Yields

Exploratory work by Trnka, *et al* (30), has indicated increases in yield through the use of liquid manure from pregnant cows which is known to contain high concentrations of animal hormones. Likewise the treatment of tubers prior to sprouting with synthetic heteroauxins (plant hormones) in concentrations of 0.00125 to 0.005 per cent produced an increase in total yield. Malcher and Medal (15) found increased yields when tubers were treated with heteroauxin.

Since these reports are from European sources and no critical analyses have been given, this information is merely suggestive for future work.

Weed Control

At least 8 different groups of workers have studied the use of synthetic plant hormones for weed control in potatoes. The rates, dates, and methods of

application appear to be important factors in whether these materials cause injury. A summary of the published results follows.

Bradley and Ellis (2) sprayed Katahdins twice during the growing season with the sodium salt of 2,4-D at rates of 0.218, 0.437, 0.655, and 0.875 pounds per acre to control smartweeds. They found no significant decreases in yield. The work was done in Indiana.

Thompson and Shuel (29) sprayed Katahdins and Cobblers with the triethanolamine salt of 2,4-D at rates of 0.8, 1.2, and 1.6 pounds per acre (acid equivalent) in both 1946 and 1947. Spraying was done after blooming. They found no reduction in yields.

Danielson (3), working in the Tidewater area of Virginia with Cobblers in 1948 and 1949, conducted significant tests. He found that there were no depressions in yield when he sprayed with either the sodium salt or the butyl ester of 2,4-D at rates of 1 and 2 pounds per acre providing this was done after barring off. The same chemicals, rates and methods of application applied when plants were 6 inches tall resulted in yield depressions of as much as 50 per cent.

Prince and Blood (19) reported on the effects of spraying six varieties of potatoes on the 16th of July, 1948, 65 days after planting, with a 40 per cent 2,4-D butyl ester formulation. The rates used were: ½ pint, 1 pint, and 1½ pints per acre. No critical data were given on yields, but it was indicated that there was approximately a 10 per cent decrease in yield for each ½ pint of "2,4-D acid" applied.

Warren and Hernandez (31) found no reduction in yield of potatoes on muck soil when 2,4-D was either mixed in the soil or sprayed on the soil surface at rates of 2 and 4 pounds per acre.

Alban and Keirns (1) made significant observations in 1948. They found that *repeated* applications of the butyl ester of 2,4-D applied at rates of 0.13 and 0.33 pounds per acre caused serious injury to Katahdins. Similar observations by Ellis (6) indicated yield depressions with the sodium salt of 2,4-D with amounts of 0.52 to 2.1 pounds per acre *when spray applications were repeated at intervals of 5 days or less.*

Smith, Meadows, and Marshall (26), in 1949, summarized three years' work on the application of 2,4-D to potatoes for weed control. They found, as have others, no injury to potatoes and fair to good weed control when the 2,4-D was applied at the time of the last hilling, at a rate of 1 pound per acre.

Rosenquist (20), working in western Nebraska in 1949, observed injury and yield depression of Bliss Triumph potatoes caused by the 2,4-D drift from airplane spraying of an adjacent field for weed control. Plants were in the early-blossom stage. No critical data were presented.

Prevention of Sprouting of Potatoes in Storage

Although McCallum (16) was probably the first to discover an effective method of breaking dormancy in potato tubers, Denny (4, 5) studied the problem extensively and established practical techniques. Guthrie (11), in 1939, published the initial discovery that the methyl ester of alphanaphthaleneacetic acid could be used to prevent potato tubers from sprouting in storage.

The details of applying the methyl ester of alphanaphthaleneacetic acid to potatoes under actual large-scale storage conditions has been studied in detail by Smith (22), Smith, Ellison, van Geluwe, and Baeza (25), Smith and Scudder (27), and Wilson and McKee (32). This compound has often been referred to as MENA.

During the 1945 season, Smith, Baeze, and Ellison (23) made a significant advance in this field when they discovered that MENA applied to *growing potato plants* later retarded sprouting of the stored tubers. It was further found (23) that this treatment often resulted in tuber injury resembling common scab. The following year Ellison and Smith (7) found that one application of MENA sprayed on growing potato plants in August significantly reduced tuber sprouting in storage without significantly reducing yields.

Smith, Ellison, and McGoldrick (24) found that 2,4,5-trichlorophenoxyacetic acid was a more potent compound for preventing the sprouting of potatoes than MENA. Used as a plant spray at 25 to 50 ppm., and applied twice, it retarded sprout growth as much as two sprayings of MENA at 2000 ppm.

Wood and Ennis (33) have also reported results of spraying potato plants at different stages of growth with the butyl ester of 2,4,5-trichlorophenoxyacetic acid. Although inhibition of tuber sprouting was accomplished, treatment, especially in the rapid-growth stages, often resulted in a tuber injury resembling common scab and similar to the injury caused by treatment with MENA. The authors suggested that the effect of the chemical was to accentuate the injury caused by the organism *Actinomyces scabies* (Guss.) Thaxt., the causal agent of common potato scab. This may be true, but it seems improbable because of the presence of stem lesions and because both pathogenic and non-pathogenic strains of *Actinomyces scabies* are inhibited in their growth by low concentrations of 2,4,5-trichlorophenoxyacetic acid (18). This point can be settled by spraying potato plants with the butyl ester of 2,4,5-trichlorophenoxyacetic acid in the presence and in the absence of *Actinomyces scabies.*

It would appear from these published reports that more reserach and information are needed before synthetic hormones of the alphanaphthaleneacetic acid or 2,4,5-trichorophenoxyacetic acid type can be recommended as plant spray treatments to inhibit sprouting in storage. Their use directly on tubers to lessen sprouting in late storage under certain conditions has been fairly well established (22, 25, 27).

Experimental Conditions and Methods

Three field experiments were designed to obtain data to answer the main objectives. These were designated as *Experiment No. 1*, tests of methods and rates of application of the sodium salt of 2,4-D to the soil; *Experiment No. 2*, tests of rates and time schedules of application of the sodium salt of 2,4-D using the plant-spray method of application; and *Experiment No. 3*, a demonstration field test of the use of the sodium salt of 2,4-D.

Arrangement of Plots

Experiment No. 1 consisted of 60 plots, 3 rows wide x 50 feet long with 5-foot alleys and double cross ditches between the ends of the plots. The plots were arranged 8 plots wide by 8 plots long (four of which were not used). The plot area was 24 rows wide x 445 feet long. The plots were further arranged in 5 blocks of uniform shape, each block containing 12 treatments. The treatments listed in table 1 were arranged at random in each block.

Experiment No. 2 consisted of 50 plots arranged in 5 blocks as in *Experiment No. 1*. Each block contained the 10 treatments, distributed at random, which are shown in table 2.

In each plot (3 rows wide and 50 feet long) the center row only was treated and harvested for yield. The side dressing treatment involved opening a shallow trench about 2 inches wide and 2 inches deep on both sides of the row near the base of the plants, followed by an application of the chemical in a liquid form. The ditch was then covered. The soil spray treatment consisted of a chemical application on the ground at the base of the plants. In *Experiment No. 2* "early application" means on the 14th of July, prebloom stage and at a time when tubers were 1 to 1½ inches in diameter and plants 16 to 18 inches tall; "late application" means the 8th of August, at a time past bloom when tubers were two-thirds grown. Row irrigation immediately followed all treatments.

Experiment No. 3 consisted of two adjacent plots, each 6 rows wide x 600 feet long. The area of each plot was 0.24 acre. One plot was treated; the other not. The treatment consisted of the spray application of the sodium salt of 2,4-D at ⅓ pound per acre (Du Pont 76 per cent acid equivalent sodium salt). The nozzles on a standard 6-row sprayer were adjusted so that the spray was applied to the lower 3 to 4 inches of plant stem and the ground at the base of the plants. The overhead nozzles were stopped up with cardboard disks. The volume of spray used was 24 gallons per 0.24 acre, or 100 gallons per acre, the usual rate of insecticide spray application on potatoes in the San Luis Valley. Spraying was followed immediately by row irrigation. All plants were treated in the early pre-bloom stage on the 15th of July and harvested on the 20th of September, 1949. All the tops were still green on this date. They were removed with a roto-beater, before digging.

Field Evaluation of Red Skin-color

Arbitrary ocular standards of skin-color were set up at harvest time. Three tubers whose colors were light red, medium red, and dark red were assigned color values of 1, 2, and 3. In evaluating the "redness" of each treatment, all plots in an experiment were dug, and where the potatoes were still on the ground, comparisons were made with the standard tubers. The evaluations for each plot were made by three workers as a check on individual error.

Yield Determinations

Data on total yields in *Experiments Nos. 1* and *2* were obtained as soon as the samples were picked up and hauled to the storage cellar. Potatoes from *Experiment No. 3* (field test) were stored, sorted for size and grade, and then weighed.

Laboratory Studies of Skin-color

The treatments in *Experiment No. 2* selected for detailed measurements of skin-color were treatment 6 (0.52 pounds per acre of the sodium salt of 2,4-D sprayed with pre-bloom and post-bloom) and treatment 10 (control, untreated). All five replications of each of these two treatments were used. These samples were selected because the five replications of the treated plots had dark red-skins and all replications of the controls light red. Also, the mean total yields of the two treatments did not differ by more than 4 per cent. Two hundred samples of uniformly sized No. 1 tubers were also selected from both the treated and the control plots in *Experiment No. 3*.

Two different techniques for studying differences in red skin-color were used. One technique employed a Schaar Photoelectric Reflection Meter, Model 610, and a green tristimulus filter in the search unit. This filter provided a spectral response approximately equivalent to observation by the human eye, in average daylight. Readings on the surface of the potatoes were expressed in terms of galvanometer readings, in which a value of 80 indicated maximum reflectance of a polished white porcelain surface. The darker the red-color of the potato skin, the lower the galvanometer reading. This direct technique was used to make comparisons of tubers from both *Experiments No. 2* and *No. 3*.

The second technique used involved extraction and concentration of the skin pigments, application of definite aliquots to large sheets of Whatman No. 1 filter paper, and, after drying, the measurement of the red color with the Schaar Photoelectric Reflection Meter. This technique was used only on samples from the field test (*Experiment No. 3*).

Method of Extracting, Concentrating and Measuring Potato Skin Pigments

Preliminary tests had indicated that in the case of the Red McClure the pigments were concentrated in the corky cell walls of the skin, and that heat

(boiling water for 2 to 5 minutes) changed the red skin-color to a faded brownish red. For these reasons, all extractions have been carried out at room temperature. The exact technique used was as follows:

Thirty tubers, selected for color, uniformity, and freedom from mechanical injuries, were washed in cold water and dried. All 30 tubers were quick frozen at —20° C., left frozen for 3 days, and thawed at room temperature for 3 hours. Skins were removed without adhering tissue, washed in running cold water 1 hour, air dried, and then dried over concentrated sulfuric acid. A 2-gram sample of dry skin was ground with 2 grams of washed, dry quartz sand in a mortar. Grinding was continued until all of the mixture passed a 0.615 mm. sieve. One gram of ground sample was extracted for 48 hours with 50 ml of 5 per cent HCl. (by volume). The filtrate was separated in a Buchner filter using suction and filter aid (white, analytical diatomaceous silica) and made up to a volume of 50 milliliters. To 25 milliliters of this acid filtrate were added three 10-ml. aliquots of n-butanol in a separatory funnel. After extraction the n-butanol extracts were bulked and reduced in volume to approximately 4 milliliters. This was done at room temperature with the aid of an electric fan. These 4-milliliter concentrates were made to a volume of 5 milliliters with n-butanol. A micropipette was then used to deposit .04-ml. aliquots at 1 x 2-inch intervals on Whatman No. 1 filter paper, size 11½ inches x 16 inches. When dry, the amount of pigment in each spot was measured with the Schaar Photoelectric Reflection Meter.

Identification of Red Potato-skin Pigments

Salaman (21), as long ago as 1910, indicated that the red pigments in the potato skin were anthocyanins. These pigments characteristically change from red to blue in an alkaline medium. The pigments extracted and concentrated in this study behaved in this manner. Separation of the several pigments present, through use of a paper chromatography technique, established the fact that the increase in red skin-color in the Na 2,4-D-treated Red McClures was an *increase* in the anthocyanins normally present. This fact is a strong supporting reason for confidence in the data secured with the Schaar Photoelectric Reflection Meter. Details of this work will be published later.

Results

Experiment No. 1.—Study of the Effect of 3 Methods and 4 Rates of Soil Application of the Sodium Salt of 2,4-D on Red Skin-color and Yield of Red McClure Potatoes.

The three methods of application tested were plants side-dressed, soil-sprayed at the base of the plants, and in the irrigation water. The four rates tested were 0, 1, 5, and 20 pounds per acre. Each treatment was replicated five times The experimental design was a randomized block. The average treatment yields are shown in table 1.

TABLE 1—*The effect of 3 methods and 4 rates of soil application of the sodium salt of 2,4-D on the yields and color of Red McClure potatoes. San Luis Valley, Monte Vista, Colorado. Experiment No. 1. Chemicals applied August 8, 1949.*

Treatment	Amount of Chemical	Method of Application	Average Total Yields per Treatment	Average Arbitrary Ocular Color Index per Treatment
			Pounds per 50 Feet of Row	*Color*
1	20 lb. Na 2,4-D/acre	Side dressed	99.2	2.40
2	5 lb. Na 2,4-D/acre	Side dressed	107.2	2.30
3	1 lb. Na 2,4-D/acre	Side dressed	98.8	2.10
4	20 lb. Na 2,4-D/acre	Soil sprayed base of plant	117.4	2.70
5	5 lb. Na 2,4-D/acre	Soil sprayed base of plant	116.2	2.30
6	1 lb. Na 2,4-D/acre	Soil sprayed base of plant	117.6	1.80
7	20 lb. Na 2,4-D/acre	In irrigation water	97.0	2.20
8	5 lb. Na 2,4-D/acre	In irrigation water	107.0	1.60
9	1 lb. Na 2,4-D/acre	In irrigation water	109.8	1.80
10	Control	No treatment	119.4	1.40
11	Control	No treatment	105.8	1.30
12	Control	No treatment	110.4	1.40

In order to determine the effects of the three methods and the four rates of application of the sodium salt of 2,4-D on the yields of Red McClure potatoes, three variance analyses were made. Since no significant differences were found in any of the categories studied, the analyses have been omitted. The following conclusions were drawn. The yields of Red McClure potatoes were not affected by the varying amounts (from 0 to 20 pounds per acre) of the sodium salt of 2,4-D, nor did the method of application of the varying amounts have any effect. The methods themselves as such did not differ significantly, nor did the amounts. Then taking each amount by itself, the methods of application within each amount did not differ significantly. Likewise, each method of application, and the amounts within each method, did not differ significantly.

The effect of each treatment for the several rates and methods of soil application of the sodium salt of 2,4-D on red skin-color are also summarized in table 1. As indicated in the section on *Experimental Conditions and Methods*, the values shown in this table were obtained by ocular comparison with three standard tubers selected at the time of harvest. A value of 1.0 for a plot meant that the predominant color was the light red, typical of untreated controls; 2.0 was indicative of medium red; and 3.0 of dark red. From these data it was noted that the nine treatments produced an average increase in red skin-color over the controls. Treatment No. 4, which was 20 pounds per acre, sprayed at the base of the plants on the 8th of August, produced the greatest increase in color without a depression in total yield. There did not appear to be any advantage in side dressing compared with spraying the base of the plants, and the application in irrigation water appeared to be less effective than the other two methods.

Experiment No. 2.—Study of the Effect of 5 Rates and 2 Time Schedules of Plant Spray Application of the Sodium Salt of 2,4-D on Red Skin-color and Yields of Red McClure Potatoes.

The rates of application used were 0.00, 0.26, 0.52, 1.04, and 1.52 pounds per acre of the sodium salt of 2,4-D. Each rate was sprayed once (late) and twice (early and late). The experimental design was a randomized block (5 blocks each with 10 treatments) making a total of 50 plots. The mean yields by treatments are shown in table 2.

In order to determine the effects of the 5 rates of application and the 2 time schedules for the spraying of the sodium salt of the 2,4-D on the yields of the Red McClure potatoes, three variance analyses were made. Since none of the categories used showed differences of any significance, the analyses are omitted. The following conclusions were drawn: The yields of the Red McClure potatoes were not affected by the varying amounts of the sodium salt of 2,4-D, nor by the time schedule of the spraying. The rates as such did not give a

TABLE 2—*The effect of the 5 rates and the 2 time schedules of plant spray application of the sodium salt of 2,4-D on the yields and color of Red McClure potatoes. Experiment No. 2 San Luis Valley, Monte Vista, Colorado, 1949.*

Treatment	Amounts	Times of Application	Average Total Yields per Treatment	Average Arbitrary Ocular Color Index per Treatment
			Pounds per 50 Feet of Row	*Color*
1	0.26 lb. Na 2,4-D/acre	Applied once (late)	112.8	1.90
2	0.52 lb. Na 2,4-D/acre	Applied once (late)	101.6	2.00
3	1.04 lb. Na 2,4-D/acre	Applied once (late)	101.4	1.90
4	1.52 lb. Na 2,4-D/acre	Applied once (late)	109.2	1.90
5	0.26 lb. Na 2,4-D/acre per treatment	Applied twice (early and late)	102.4	2.90
6	0.52 lb. Na 2,4-D/acre per treatment	Applied twice (early and late)	108.6	2.90
7	1.04 lb. Na 2,4-D/acre per treatment	Applied twice (early and late)	93.0	3.10
8	1.52 lb. Na 2,4-D/acre per treatment	Applied twice (early and late)	96.8	3.10
9	Control	No treatment	115.8	1.00
10	Control	No treatment	108.4	1.00

difference in yields, nor did the two-time schedules have any appreciable difference in effect. Likewise, comparisons of the yields within each time schedule showed no significant difference because of the varying rates of application of the chemical, nor did the effects caused by the time schedules within each rate of application have an appreciable difference in their effects on the yields. Apparently it made no difference which one of the amounts of the sodium salt of 2,4-D was used, nor did it matter whether the extra early spraying was made.

The effects of the 5 rates and the 2-time schedules of plant spray application of the sodium salt of 2,4-D on red skin-color are also summarized in table 2. Under the conditions of the experiment, treatments 7 and 8 produced the greatest increase in red skin-color. These treatments were 1.04 pounds and 1.52 pounds per acre applied twice (early and late). Treatments 5 and 6, *i. e.*, 0.26 pounds and 0.52 pounds applied twice, were almost as good. The analysis of variance of yields indicated no significant difference between these 4 treatments, *i. e.*, between treatments 5, 6, 7, and 8, so that all four of them might probably be considered almost equally effective. The average color index for the once-treated plots (late treatment) was 1.925, and of the twice-treated (early and late) 3.000.

Experiment No. 3.—Demonstration Field Test of the Effect of the Sodium Salt of 2,4-D on Red Skin-Color and Yield of Red McClure Potatoes.

Yields.—The total yield of the treated plot (0.24 acre) was 5310 pounds, and of the control plot 5590 pounds. On an acre basis this was equivalent to 22,125 and 22,458 pounds, or 221 and 224 100-pound bags per acre, respectively. These differences are so small that there is little chance of significance.

Direct-Measurements of Skin-color at Harvest Time of Red McClure Potatoes

The direct measurement of skin-color at harvest time employed the Schaar Photoelectric Reflection Meter, Model 610, as previously described. Ten readings on the surface of each of 20 potatoes, selected for size and uniformity, from the treated plot and also from the untreated or control plot, were recorded. The mean galvanometer readings for these samples are shown in table 3.

For the purpose of statistical analysis, these data may be considered in two ways: the potatoes may be called the replications or the positions on the potato may be regarded as such. The four variance analyses made, two for each approach, are presented in table 4. As might be surmised from table 3, where the plot treated with the sodium salt of 2,4-D had a much lower mean reading than the non-treated or control plot, there was a very highly significant difference between the red skin-color of those treated and those not. The variability between positions on the potato was not significant. However, after what little effect on color that was caused by position had been removed, the treated plots were still darker than the untreated.

Considering each of the plots separately, it was apparent that some of the difference in the color was due to the potatoes themselves. Within each plot the potatoes differed significantly. It was interesting to note, however, that after the variability caused by the potatoes had been removed there were still significant differences in color between the treated and untreated plots.

TABLE 3—*The effect of treatment with the sodium salt of 2,4-D on the red skin-color of Red McClure potatoes as measured by the Schaar photoelectric reflection meter at time of storage. October 5, 1949*

Demonstration Field Test Experiment No. 3

Number of Potato	Red Color Index[1]	
	Control Mean of 10 Galvanometer Readings for Each Potato	Na 2,4-D @ 1/3/Acre Plant Sprayed; Mean of 10 Galvanometer Readings for Each Potato
1	42.28	39.61
2	44.55	41.04
3	43.55	40.85
4	43.52	40.61
5	44.90	40.60
6	42.88	40.43
7	41.36	40.56
8	43.05	41.41
9	42.95	40.38
10	42.47	40.05
11	42.32	40.88
12	41.64	41.54
13	42.77	41.34
14	42.02	40.15
15	43.30	41.64
16	42.90	39.93
17	42.85	43.55
18	44.46	43.61
19	42.95	39.73
20	44.35	42.05
	Mean 43.05	Mean 40.99

[1] These are galvanometer units read on a Schaar Photoelectric Reflection Meter, Model 610, and are a measure of "apparent luminous reflectance" or "lightness." A standard polished white porcelain surface produced a galvanometer reading of 80. The *darker red* the color *the lower* the readings.

TABLE 4—*Variance analyses of the field test of the effect of the sodium salt of 2,4-D on the red skin-color of Red McClure potatoes.*

Variability Due to:	D/F	Sums of Squares	Mean Square	Observed F	Required F .05	Required F .01
1.						
Totals	399	1445.10				
Between treatments	1	422.71	422.71	164.48	3.86	6.70
Within treatments	(398)	(1022.39)	2.57			
Between positions Within treatments	18	24.90	1.38	Less than unity	....	....
Within positions Within treatments	380	997.49	2.62	Less than unity		
2.						
Totals	399	1445.10				
Between positions	9	11.56	1.285	Less than unity	....	....
Within positions	(390)	(1433.54)	3.676	Less than unity		
Between treatments Within position	10	436.05	43.054	16.40	1.85	2.37
With treatments Within positions	380	997.48	2.625			
3.						
Totals	399	1445.10				
Between treatments	1	422.71	422.71	164.48	3.86	6.70
Within treatments	(398)	(1022.39)	2.57			
Between potatoes Within treatments	38	403.59	10.62	6.18	1.43	1.65
Within potatoes Within treatments	360	618.80	1.72			
4.						
Totals	399	1445.10				
Between potatoes	19	444.52	23.396	8.89	1.62	1.95
Within potatoes	(380)	(1000.58)	2.633			
Between treatments Within potatoes	20	381.78	19.089	11.11	1.60	1.93
Within treatments Within potatoes	360	618.80	1.719			

These data indicate that the treatment with the sodium salt of 2,4-D will produce a darker red skin-color in Red McClure potatoes than that of the untreated controls, without yield depressions.

Changes in Red Skin-color between the Time of Early Tuber Formation and Harvest

It has been a common observation by growers that during the period of rapid tuber formation, skin-color is a brilliant dark red, but as tubers mature they lose much of this desirable color. This series of tests was designed to determine if treatment with the sodium salt of 2,4-D actually increased the amount of skin pigments or whether it stabilized that which was already present in the young tubers. The methods of extraction, concentration, and the measurement of pigments have already been described. The sources of samples for all tests were the treated and control plots in the field test.

The data are summarized and analyzed in table 5. When dates of sampling as such are considered, there is a decided difference in red color between the treated and control plots, but these differences are not so great as between dates within treatments. The conclusion is that there are very highly significant differences between treatments within dates, as well as between dates within treatments. It is noted that there was an increase in red color in the samples from both the control and treated plots between the 14th of July and the 26th of August. This is indicated by the decreases in mean galvanometer readings shown in table 5. After the 26th of August there was a decided loss of red color in samples from both the control and treated plots. In spite of this, at harvest time, on the 21st of September, the sample from the treated plot was significantly darker red than the sample from the control plot. The conclusion, therefore, is that treatment with the sodium salt of 2,4-D increased but did not stabilize the amounts of red pigments present in young tubers. This is indicated by the fact that the tubers from the treated plot increased in redness between the 14th of July and the 26th of August, but lost color between the 26th of August and the time of harvesting on the 21st of September.

Discussion

The results of the studies reported in this paper support those previously published for Bliss Triumph (9), *i. e.*, the sodium salt of 2,4-D may be used either as a side dressing, as a spray at the base of the plants, in irrigation water, or as a plant spray to increase red skin-color in Red McClures without reducing yield. These results also agree with those of Bradley and Ellis (2), Thompson and Shuel (29), Danielson (3), Warren and Hernandez (31), and Smith, Meadows and Marshall (26), in the finding that low amounts (¼ to 1½ pounds per acre) of 2,4-D may be applied to potatoes at the late pre-bloom to early post-bloom growth stages without significantly depressing yields.

TABLE 5—*The effect of date of sampling and 2,4-D treatment on the amounts of extractable red pigments in the skin of Red McClure potatoes. Demonstration field test. Experiment No. 3.*

GROUP COMPARISONS

Harvest Date	Stage of Growth	Red Color Index[1]			
		2,4-D Treated		Control	
		N	Mean	N	Mean
July 14	Pre-bloom tubers ¾"	50	76.34	50	76.07
July 26	Full-bloom tubers 1"	50	69.97	50	75.88
August 12	Post bloom tubers 1½"	50	68.88	50	74.04
August 26	Tubers 2/3 grown	50	67.04	50	71.95
September 21	Mature, vines green	50	73.06	50	73.03
	Treatment Means	250	71.058	250	74.374

VARIANCE ANALYSES

Variability Due to:	D/F	Sums of Squares	Mean Square	Observed F	Required F .05	Required F .01
1.						
Totals	499	5093.672				
Between treatments	1	1374.482	1374.482	184.04	3.86	6.69
Within treatments	(498)	(3719.190)	7.468			
Between dates Within treatments	8	3265.410	408.176	440.76	1.96	2.55
Within dates Within treatments	490	453.780	0.926			
2.						
Totals	499	5093.672				
Between dates	4	2477.702	619.400	117.20	2.39	3.36
Within dates	(495)	2616.070	5.285			
Between treatments Within dates	5	2162.290	432.458	466.98	2.23	3.06
Within treatments Within dates	490	453.780	0.926			

Standard deviation = 0.962 Standard error = 0.136
Minimum difference required for significance (treatments by dates) at .05 level = 0.378
at .01 level = 0.498

[1] These are galvanometer units read on a Schaar Photoelectric Reflection Meter, Model 610, and are a measure of "apparent luminous reflectance" or "lightness." A standard polished white porcelain surface produced a galvanometer reading of 80. The *darker red* the color, *the lower* the readings.

Not all methods and rates of application are equally desirable for further testing on Red McClure potatoes. From the results secured, it would appear that the methods used in *Experiment 3* (the demonstration field test) warrant further testing. It will be recalled that in this test the rate of application was 1/3 pound of the sodium salt of 2,4-D per acre applied as a spray directed toward the lower plant stems. The volume of spray used was 100 gallons per acre applied in the late pre-bloom stage. Spraying was followed by a row irrigation.

Detailed consideration of the results from *Experiment 2* indicates that amounts of less than 1 pound per acre may be effective. Treatment No. 5, 0.24 pounds per acre applied at both pre-bloom and again 3 weeks later, produced almost as dark red tubers as the 1.04 and 1.52-pound rates applied twice.

Single post-bloom spray treatments did not produce as dark-red colored tubers as did single pre-bloom treatments nor as did one pre-bloom plus one post-bloom application. Considerable leeway was indicated for all three methods of ground application. Rates of 1, 5, and 20 pounds per acre produced no significant yield depressions.

Although no extensive critical data covering the effects of the sodium salt of 2,4-D on sprouting of Red McClures is yet available, tests with three other synthetic plant hormones during the 1948 season (10) showed no abnormal sprouting after 7 months' storage. Field observations on the same samples grown at Del Norte, Colorado, during the 1949 season failed to show abnormal stands, growth or yield reductions.

The data secured by the use of the Schaar Photoelectric Reflection Meter complement the data secured by ocular methods. The reflection meter method appear to have the advantage of being reproducible and does not depend on differences in individual personal color perception.

The detailed study of red skin pigments furnished *comparative* quantitative data on the amounts present in tubers from both control and 2,4-D treated plots. Relative amounts of pigments were studied between the pre-bloom stage and harvest. The treatment produced an immediate increase in red pigments which decreased in absolute amount during the last month before harvest. However, at harvest there were still significantly greater amounts of pigment in the treated tubers.

Additional investigations including studies of the effect of treatment on vitamin C content and specific gravity are in progress. Further field tests are also contemplated to determine seasonal effects and to evaluate the factors of soil fertility levels and possible residual effects.

Summary

This study indicated that the sodium salt of 2,4-D may be used to increase the red skin-color of Red McClure potatoes without causing a reduction in yield.

Literature Cited

1. Alban, E. K., and V. E. Keirns. 1948. Pre-emergence and post emergence weed control in vegetable crops with 2,4-D and oil. Proc. Amer. Soc. Hort. Sci. 51:526-532.
2. Bradley, R. H., and N. K. Ellis. 1948. The effect of different rates of application of 2,4-D on the yield of potatoes. Amer. Potato Jour. 25:87-89.
3. Danielson, L. L. 1949. Weeding Irish potatoes with 2,4-D. Amer. Potato Jour. 26:1-7.
4. Denny, F. E. 1926. Hastening the sprouting of dormant potato tubers. Amer. Jour. Bot. 13:118-125.
5. ———. 1926. Second report on the use of chemicals for hastening the sprouting of dormant potato tubers. Amer. Jour. Bot. 13:386-397.
6. Ellis, N. K. 1949. The effect on the yield of potatoes of incorporating 2,4-D in the regular spray. Amer. Potato Jour. 26:208-213.
7. Ellison, J. H., and Ora Smith. 1948. Effects of spraying a sprout inhibitor on potato plants in the field. Proc. Amer. Soc. Hort. Sci. 51:397-400.
8. Erickson, Wilbur G. 1949. Red McClures, the high altitude all-purpose potatoes. Folks and Fortunes 1:33-36. Monte Vista Journal, Monte Vista, Colo.
9. Fults, Jess, and L. A. Schaal. 1948. Red skin color of Bliss Triumph potatoes increased by the use of synthetic plant hormones. Sci. 108:411.
10. ———, W. E. Pyke, L. A. Schaal, R. E. Carlson and Nellie Landblom. 1949. Plant hormone studies on potatoes. Colo. Agr. Exp. Sta. and Bur. Plant Ind., U. S. D. A. (Mimeographed).
11. Guthrie, John D. 1939. Inhibition of the growth of buds of potato tubers with the vapor of methyl ester of naphthaleneacetic acid. Contr. Boyce Thompson Inst. 10:325-328.
12. Gregory, J. S., and R. Kunkel. June, 1949. Importance of red color in marketing. Spud Notes. Colorado A. & M. College, Fort Collins, Colo.
13. Kunkel, R. February, 1949. Report on experimental and demonstration work of the San Luis Valley farm. Colorado A. & M. College and Extens. Serv., Fort Collins, Colo. (Mimeographed).
14. ———. July, 1949. Progress report on potato research in the San Luis Valley, 1946-1948. Depts. of Horticulture, Soils and Extension Service. Colorado A. & M. College, Fort Collins, Colo. (Mimeographed).
15. Malcher, J., and C. K. Medal. 1943. Investigations with hormones on plants grown for use in the production of alcohol. Vestnik. Ceske, Akad. Zmedelske 19:162-168.
16. McCallum, W. B. 1909. Physiological Ann. Rept. Ariz. Agr. Exp. Sta., 1909:584-586.
17. McLean, John G., Walter C. Sparks and A. M. Binkley. 1944. The effect of certain minor elements on yield, size and skin thickness of potato tubers. Proc. Amer. Soc. Hort. Sci. 44:362-368.
18. Michaelson, M. E. 1949. Some effects of 2,4-dichlorophenoxyacetic acid, its salts and esters on several physiologic strains of the potato scab organism *Actinomyces scabies* (Thaxt.) Guss. Master's Thesis. Bot. and Plant Path. Dept., Colorado A. & M. College, Fort Collins, Colo.
19. Prince, F. S., and P. T. Blood. 1949. The effects of 2,4-D on potato tops and tubers when sprayed at the full-bloom stage. Agron. Jour. 41:219-220.
20. Rosenquist, C. E. 1949. Effect of drift of 2,4-D spray on Irish potatoes. Amer. Potato Jour. 26:80-81.
21. Salaman, R. N. 1910. The inheritance of color and other characters in the potato. Jour. Genet. Cambridge, 1:7-46.
22. Smith, Ora, 1946. Sprout stopper retards storage growth of potatoes and root crops. Food Packer 27(13):61-63.
23. ———, M. A. Baeza and J. H. Ellison. 1947. Response of potato plants to spray applications of certain growth-regulating substances. Bot. Gaz. 108:421-431.
24. ———, J. H. Ellison and Fred McGoldrick, 1949. Growth of potato sprouts retarded by 2,4,5-trichlorophenoxyacetic acid. Science 109:66-68.

25. ———, J. H. Ellison, J. van Geluwe and M. A. Baeza. 1946. Sprout preventer new chemical formula retards sprout growth damaging stored root crops. Southern Seedsman 9(10): 13, 50, 54 and 59.
26. ———, M. W. Meadows and E. R. Marshall. 1949. Control of weeds in potatoes by pre-emergence sprays. Proc. Northeastern States Weed Control Conf. 1949: 98-113.
27. ———, and W. T. Scudder. 1947. Potato growers enthusiastic about "sleeping potion" chemical. Farm Research 13(3):7. Ithaca, N. Y.
28. Sparks, Walter C. 1944. The effect of certain minor elements on the skin color of potatoes as measured by the multiple disk colorimeter. Proc. Amer. Soc. Hort. Sci. 44:369-378.
29. Thompson, M. R., and R. W. Shuel. 1948. Weed control in potatoes with 2,4-D. Amer. Potato Jour. 25:163-171.
30. Trnka, R., V. Frantek and L. Praskac. 1944. Hormonization and fertilization with commercial fertilizers III. Shornik, Ceske. Akad. Zemedelske 17:214-221; 1942. Chem. Zentr. II, 1106.
31. Warren, G. F., and T. P. Hernandez. 1948. Weed control in certain vegetable crops with soil applications of 2,4-D. Proc. Amer. Soc. Hort. Sci. 51:515-525.
32. Wilson, A. R., and R. K. McKee. 1948. Prevention of excessive sprouting in late-stored ware potatoes. Agriculture: The Jour. of Ministry of Agric. 55 (No. 7): 296-299.
33. Wood, Don C., and W. B. Ennis, Jr. 1949. Influence of butyl 2,4,5-trichlorophenoxyacetate upon the development of tuber abnormalities in Irish potatoes. Agron. Jour. 41:304-308.

AIR AND SOIL TEMPERATURES IN POTATO FIELDS, KERN COUNTY, CALIFORNIA, DURING SPRING AND EARLY SUMMER[1]

O. A. Lorenz

Division of Truck Crops, University of California, College of Agriculture Davis, Cal.

(Accepted for publication May 10, 1950)

Maximum air temperatures in the potato fields in Kern County, California, during May and June are sometimes over 100 degrees F. The study reported here was undertaken to compare air and soil temperatures during the spring and early summer and to determine any relationship between high soil temperatures and internal browning of potato tubers. This injury, often referred to as "heat" or "drought" necrosis, seems to occur near the time of harvest. The study was later expanded to include the effects of irrigation and of shading upon temperatures of the soil. Only soil and air temperatures are discussed in this paper.

Review of Literature

Smith (6) (7) made intensive studies of soil and air temperatures of Central California soils and noted especially the daily and seasonal fluctuations at various depths. Most of his data were obtained from bare, uncultivated, and unirrigated soils. Bliss, Moore, and Bream (2) studied air and soil temperatures in a date garden at Indio, California, and Bliss (1) did the same for a citrus orchard near Anaheim, California.

The influence of air temperatures on the production of potatoes has been studied by Bushnell (3), Smith (10), and Werner (12). They found the average air temperature for optimum potato production to be approximately 64°F. When the average temperature rose above 68F. the yields were proportionately reduced.

Metzger (5) inferred that soil temperatures play an important part in tuber production, for he stated that the effects of high temperature could be combatted by cultivation, by irrigation, and by close planting so that vines would shade the ground by the time tubers begin to form. He did not, however, give data to show the degree to which these various factors affect soil temperature.

Methods

In the present study, temperatures in potato beds were recorded at the three-, six-, and nine-inch depths during the growing seasons of 1945, 1946, and 1948. Continuous records were obtained from distance thermographs

[1] The author wishes to thank Mr. George J. Harrison, Agronomist, U. S. Cotton Field Station, Shafter, California, for supplying some of the instruments and for aid in obtaining part of the data, and also Mr. James Bishop of the Division of Truck Crops, University of California, for help in obtaining the data in 1948.

located in fields at the U. S.D. A. Cotton Experiment Station at Shafter, California. The soil at this location is classified as Hesperia fine sandy loam. Most of the temperature data were from the six-inch depth, since work previously reported (4) had shown that the majority of tubers are found from four to six inches below the top of the ridge. The thermometer bulbs were placed in the center of the ridge. Air temperatures were taken from a continuous recording thermograph located in a Standard U. S. Weather Bureau shelter about one hundred yards from the potato fields, where the soil records were made.

Most of the temperature data are reported as weekly averages, since it was the purpose in most comparisons to show the general soil temperatures throughout the entire growing season. These averages were obtained by reading the daily maximum and minimum temperatures from the weekly recording charts and then averaging them for the seven-day period. Several graphs are presented to show the daily fluctuation. The curves in figure 3 present half-hourly readings taken from the weekly recorded chart. The daily times given are for Pacific Daylight Saving time.

The potatoes were grown according to regular commercial methods. The land was irrigated prior to planting and then received no further irrigation until nearly two weeks after the crop was up. Soon after, daily irrigations were applied in alternate furrows. The plants were spaced approximately one foot apart in beds 32 inches apart. Approximately 600 pounds of ammonium sulfate fertilizer was applied at the time of planting. Soon after planting, the ridges were made to the final height of approximately eight inches above the bottom of the furrow. In 1945, the potatoes were planted on February 19 and harvested on June 18; in 1946, corresponding dates were February 14 and June 18; and in 1948, the dates were February 9 and June 29, respectively. Plant emergence was approximately April 1, March 14, and March 10 for the years 1945, 1946, and 1948, respectively.

Results

The records obtained may be conveniently grouped into three categories: (1) a study of air temperatures and soil temperatures, the latter measured at various depths in the bed; (2) a comparison of soil temperatures in irrigated and non-irrigated beds; some planted and some fallow; (3) comparisons between fallow and cropped plots to determine the effect of foliage cover on soil temperature. During 1948, one series of fallow plots was artificially shaded to determine the possible effect of exceedingly heavy foliage cover.

Air and Soil Temperature Measurements

Weekly averages of air temperature and soil temperature six inches below the top of the ridge are presented in figure 1. In 1945, the plants had been

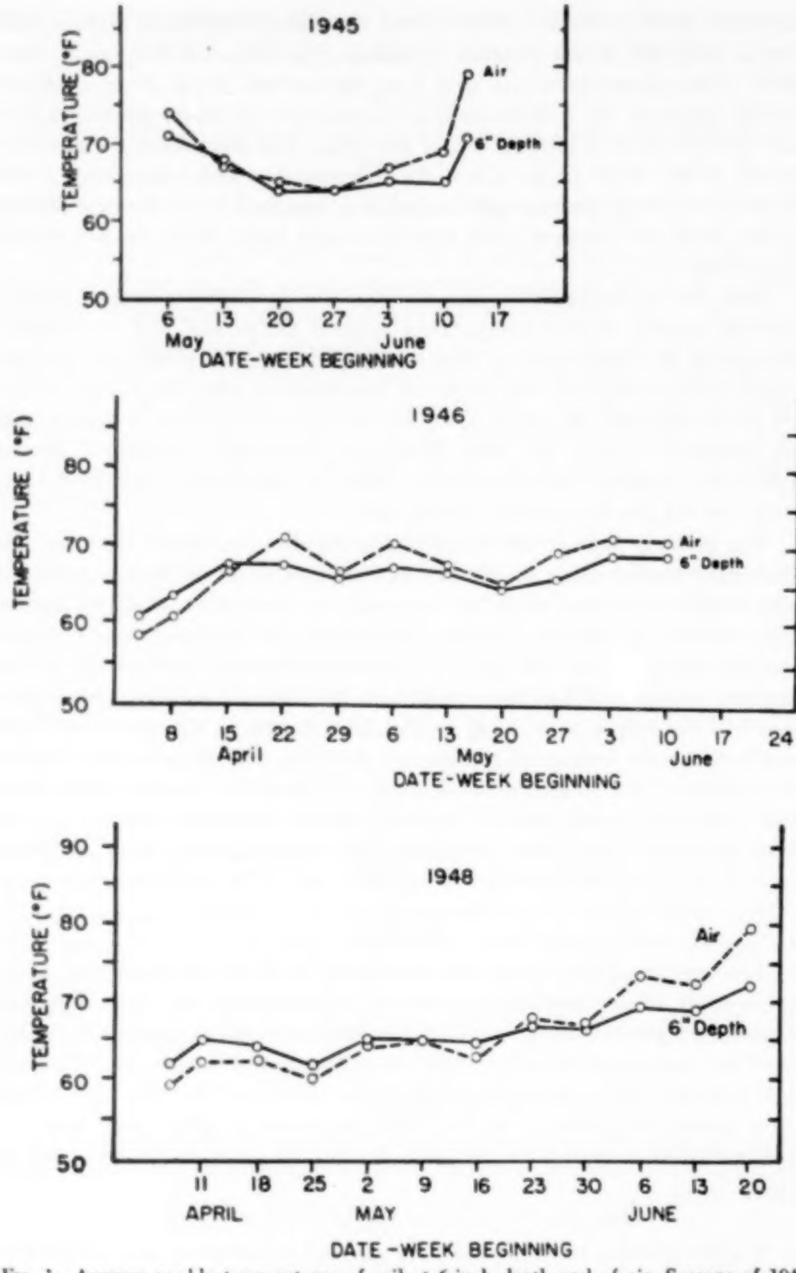

FIG. 1—Average weekly temperatures of soil at 6-inch depth and of air. Seasons of 1945, 1946 and 1948.

up about one month and were approximately 15 inches tall before the first temperature records were made. In 1946 and 1948, temperature records were begun soon after the plants emerged. In early April, the soil temperature averaged about 60°F., as compared with an average of approximately 65°F. for May, and 70°F. or above for June. During April, the soil temperature averaged several degrees warmer than the air; during May they were very nearly the same. In June, the temperatures were reversed, the air temperature averaging several degrees above that of the soil. The normal monthly air temperature for this area as obtained at the Bakersfield Airport by the U. S. Weather Bureau (11) is 62.8°F. for April, 70.7°F. for May, and 70.7°F. for June.

The soil temperatures at the six-inch depth for each of the three years are presented in figure 2. These were markedly similar for each of the years,

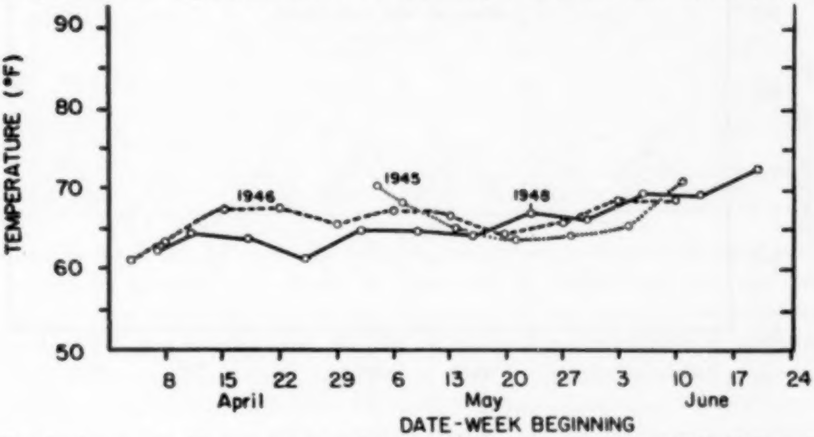

FIG. 2—Average weekly temperatures of soil at 6-inch depth. Seasons of 1945, 1946, and 1948.

especially during May, when most of the tuber growth was occurring. The temperature during this month averaged very close to the 64°F. optimum described by Bushnell (3).

The data showing typical diurnal fluctuations in temperature at the three-, six-, and nine-inch depths are given in figure 3. On clear sunny days, temperatures at the three-inch depth fluctuated more than 20°F., whereas at the six-inch depth comparable fluctuations were less than 15°F., and at the nine-inch depth, less than 8°F. These results agree fairly well with the data of Smith (8), where bare and paper-covered plots at Davis showed daily variations of approximately 20°F., at the three-inch depth. Bliss (1), in a partially shaded orange grove at Anaheim, found slightly more than 20 degrees variation at the three-inch level and about 14 degrees at the six-inch level on a warm clear summer day.

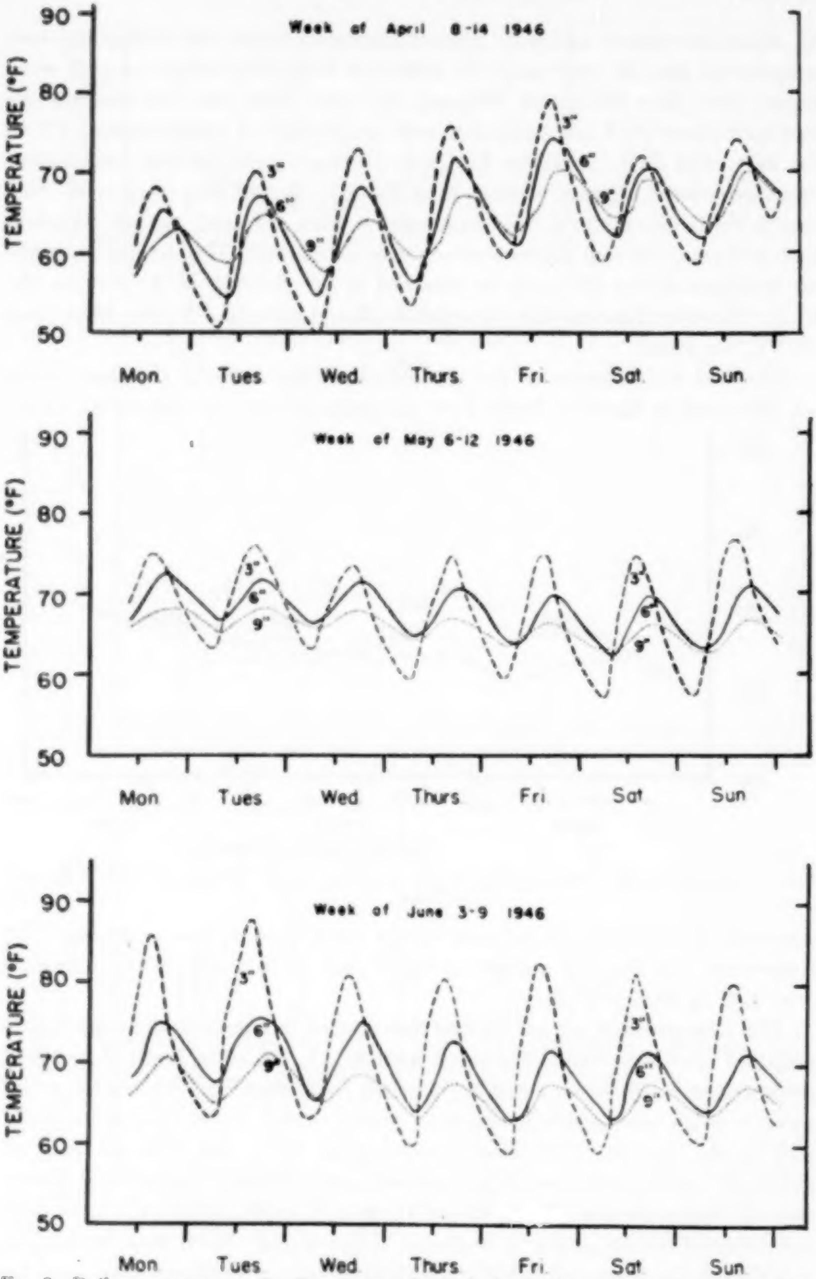

FIG. 3—Daily temperatures of soil at 3, 6, and 9-inch depths for weeks beginning April 8, May 6, and June 3, 1946.

The maximum temperatures in the potato beds were reached at approximately 3:00, 5:00, and 7:00 p. m. (Daylight Saving Time) for the three-, six-, and nine-inch depths, respectively. Smith (8), at Davis, found maximum soil temperatures at the three-inch level at approximately the same time as in the potato fields.

When the entire growing period of April through June was taken into account, there was very little difference between the average temperature of the air or of the soil at the three-, six-, or nine-inch depths. The seasonal changes in the temperatures of the air and of the soil are illustrated in table 1.

TABLE 1—*Air temperature and soil temperatures at various depths during three weeks of 1946.*

Station Recorded	Average Temperature (°F) for Week Beginning		
	April 8	May 6	June 3
Air	60.9	70.9	71.4
Soil 3" depth	62.6	66.3	70.7
Soil 6" depth	63.7	67.5	68.9
Soil 9" depth	63.6	65.5	66.6

During the month of April ,the soil temperature was warmer than the air and tended to increase with depth. In June, the air temperature average was higher than that of the soil. During this month the soil temperature decreased with depth and for the week of June 3, at the three-inch depth it averaged 70.7°F., as compared with 68.9°F. and 66.6°F. for the six- and nine-inch depths, respectively. Both Bliss (1) and Smith (7) had found that the seasonal overturns in soil temperatures occurred during the months of April and May.

Effect of Foliage Cover and Shading on Soil Temperature

Average soil temperatures of fallow and of planted beds at the six-inch depth during the 1946 season are presented in figure 4. Both series of beds received daily irrigations in alternate furrows. The plants emerged about March 15 and by April 15 were approximately 12 inches tall and 12 inches in diameter. By early May, there was almost complete foliage cover of the soil of the bed. Until the week of April 22, the soil temperature of the planted beds was only about two degrees cooler than that of the cropped beds, but from the first of May until harvest, the planted beds were approximately eight degrees cooler than the fallow beds. The small difference in temperature between the fallow and cropped plots during early April was probably caused by the fact that the foliage gave only partial shading to the soil. Later in the

season, good foliage cover accounted for a cooling of nearly eight degrees below that of bare soil. This agrees with the results of Bliss (1), who found shaded soil at the three-inch level to average about six to nine degrees below that of exposed soil, whereas the maximum temperatures at the three-inch depth were more than 20 degrees cooler in shaded than in unshaded soil. In a field of Hubam clover, 18 inches tall, Smith, Kinnison, and Carns (9) found the soil temperature at the two-foot depth to average about eight degrees below that of bare soil.

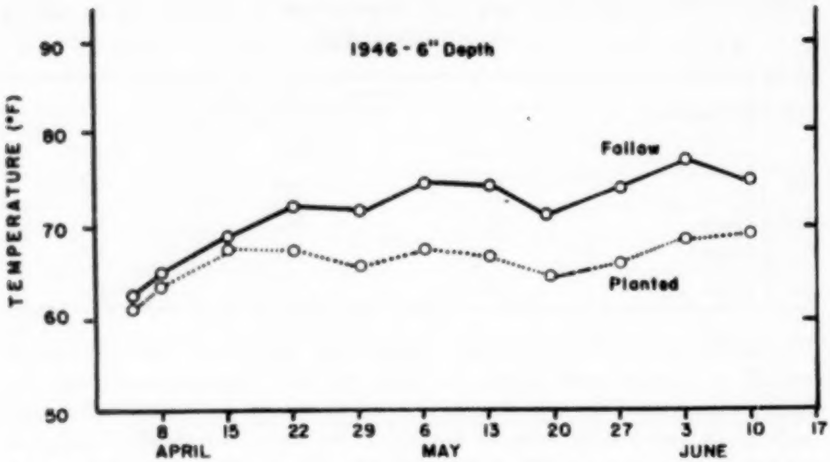

FIG. 4—Average weekly temperatures of soil at 6-inch depth of fallow and planted bed, 1946.

In 1948, comparisons were made of planted beds, fallow beds, and fallow bed artificially shaded. This third group was shielded completely from the sun with a large piece of plywood placed about 12 inches above the top of the ridge and so mounted that air moved freely underneath. Such an arrangement should give information as to the maximum cooling possible by foliage cover. It might, however give even greater cooling than that obtained with foliage cover, since air could move freely under the board. The evaporative cooling might be greater than that of the foliage cover, since the latter would restrict air passage. Conversely, though, the board would radiate heat to the soil during the day and at night might hinder radiation from the soil to the sky. The data show that after the first of May, soil of the planted plots averaged six to eight degrees less than that of the fallow plots, as shown in figure 5. Likewise, the artificially-shaded beds averaged two to four degrees cooler than the planted beds.

Effect of Irrigation on Soil Temperature

The effect of furrow irrigation on cooling of the soil was tested in planted beds in the following manner. Beds with comparable foliage cover were selected. All were irrigated until the day the test was begun, after which one series of beds received no further irrigation, whereas a second series received daily irrigations in alternate furrows. The results of six such tests conducted during the growing seasons of 1945 and 1946 are presented in figures 6 and 7. The most reliable data showing the true effect of irrigation would be those obtained from three to six or eight days after the last irrigation on the non-irrigated beds. At this time, the soil surface would be dry, although the plants would not have begun to wilt severely. Wilting caused the vines to open up and exposed some of the soil to the sun. Comparable cooling was obtained for both the maximum and average daily temperatures. In every test the soil temperature at the six-inch depth was cooler in the irrigated beds than in those not irrigated. The maximum amount of cooling observed in the area of tuber set was about six degrees, four degrees being a good average. This was true whether the records were obtained in early April when the foliage gave only partial cover to the bed, or in late May when the foliage almost completely shaded the ground.

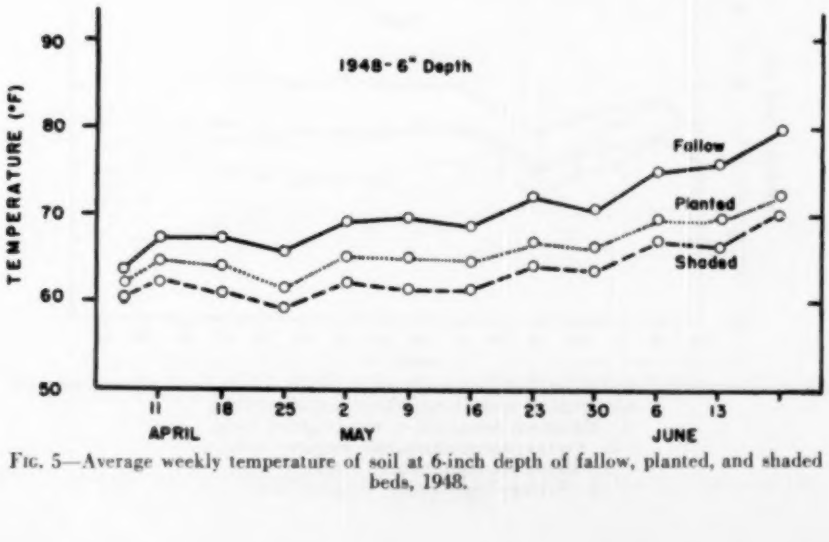

Fig. 5—Average weekly temperature of soil at 6-inch depth of fallow, planted, and shaded beds, 1948.

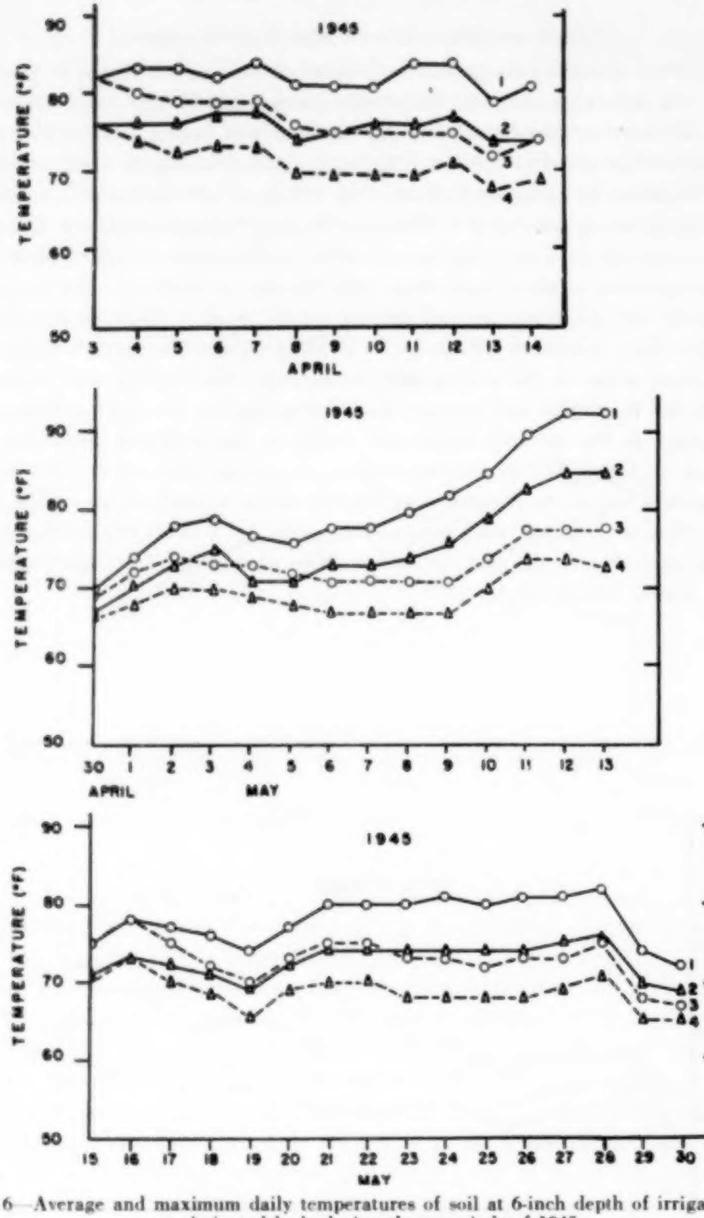

Fig. 6—Average and maximum daily temperatures of soil at 6-inch depth of irrigated and non-irrigated beds during three periods of 1945.

1. Maximum temperature, non-irrigated beds.
2. Average temperature, non-irrigated beds.
3. Maximum temperature, irrigated beds.
4. Average temperature, irrigated beds.

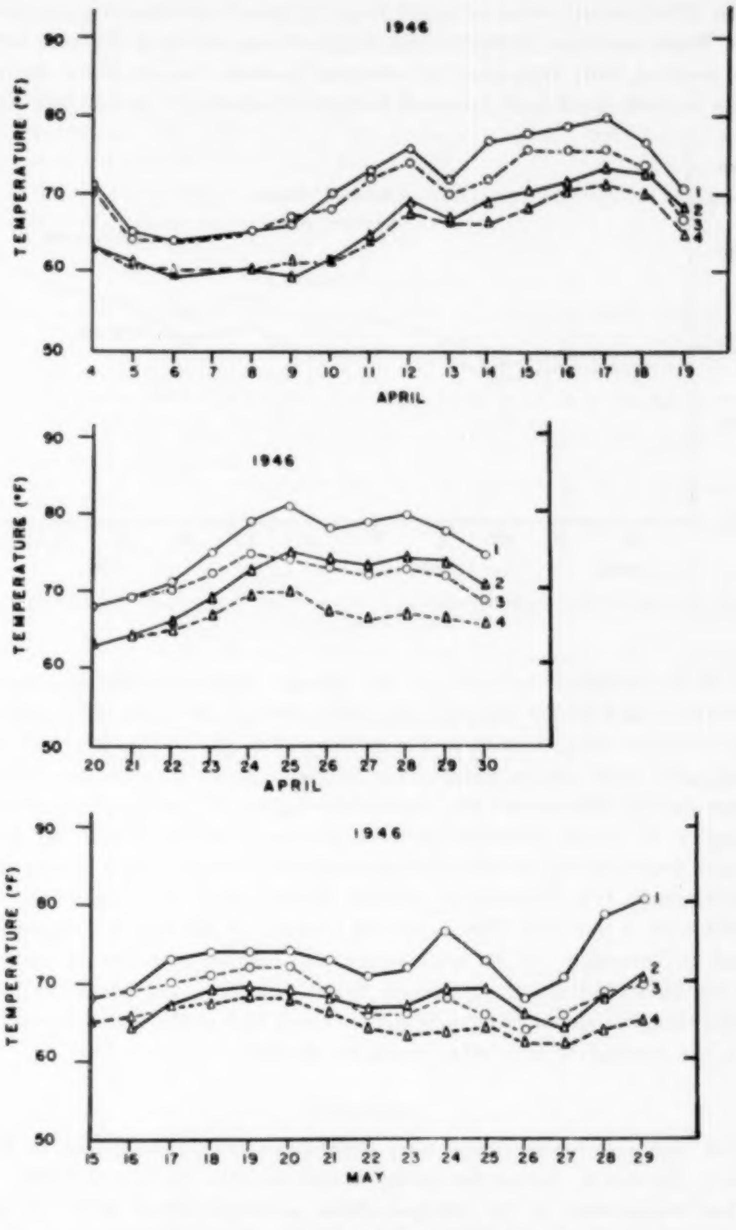

FIG. 7—Air and soil temperature in potato fields, Kern County, California, during spring and early summer.

In 1948, records were obtained from irrigated and non-irrigated fallow beds. Water was first applied to the irrigated beds on April 17, after which they received daily irrigations in alternate furrows. Temperatures obtained at the six-inch depth and presented in figure 8 show that, during late April,

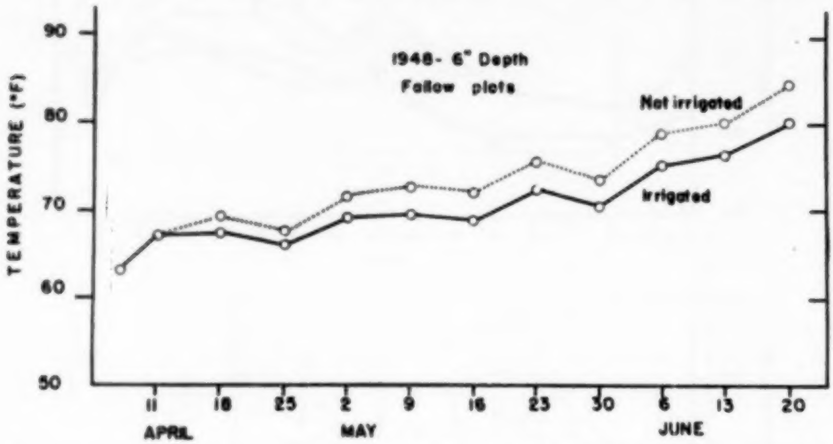

FIG. 8—Average weekly temperatures of soil at 6-inch depth of irrigated and non-irrigated fallow beds, 1948.

soil of the irrigated bed was on the average, approximately two degrees cooler than that of the non-irrigated beds. During May, the difference was approximately three degrees, and near the end of the test in June, the irrigated beds were approximately four degrees cooler. It appeared that the higher the air temperature the greater the degree of cooling of the soil by irrigation. It would seem that growers planting potatoes in this soil at the six-inch depth during periods of high temperature might expect a cooling of approximately four degrees, or possibly slightly more, in irrigated as contrasted with a dry soil. The degree of cooling of the soil by evaporation would be dependent on the temperature and relative humidity of both the soil and air and on the air movement. Smith, Kinnison, and Carns (9) found cooling as great as ten degrees in a very sandy soil of the Yuma Mesa, Arizona, the average cooling being about six degrees.

SUMMARY

Air and soil temperatures were determined in potato fields, in Kern County, California, during the spring months of 1945, 1946, and 1948.

Soil temperature at the six-inch depth averaged about 60°F. in early April, 65°F. in May, and 70°F. in June. During April, the soil averaged several degrees above that of the air, whereas the reverse was true during June.

Diurnal fluctuations in planted beds often were more than 20°F. at the three-inch depth, whereas comparable fluctuations at the six-inch depth were less than 15°F., and less than 8°F. at the nine-inch depth.

Shading the soil by good foliage growth accounted for a cooling of about eight degrees, as compared with fallow beds. Completely shaded beds averaged about ten degrees cooler than fallow beds.

On the average, irrigated beds were about four degrees cooler at the six-inch depth than those unirrigated.

Literature Cited

1. Bliss, Donald E. 1944. Air and soil temperatures in a California citrus orchard. Soil Sci. 58:259-274.
2. ———, D. C. Moore, and C. E. Bream. 1942. Air and soil temperatures in a California date garden. Soil Sci. 53:55-64.
3. Bushnell, John. 1925. The relation of temperature to growth and respiration in the potato plant. Minn. Agr. Exp. Sta. Tech. Bull. 34. 29 pp.
4. Lorenz, O. A. 1945. Effect of planting depth on yield and tuber set of potatoes. Amer. Potato Jour. 22:343-349.
5. Metzger, C. H. 1938. Growing better potatoes in Colorado. Colo. Agr. Exp. Sta. Bull. 446. 127 pp.
6. Smith, Alfred. 1929. Comparisons of daytime and nighttime soil and air temperatures. Hilgardia 4:241-272.
7. ———. 1929. Diurnal, average and seasonal soil temperature changes at Davis, California. Soil Sci. 28:457-468.
8. ———. 1931. Effect of paper mulches on soil temperature, soil moisture, and yields of certain crops. Hilgardia 6:159-201.
9. Smith, G. E. P., A. F. Kinnison, and A. F. Carns. 1931. Irrigation investigations in young grapefruit orchards on the Yuma Mesa. Ariz. Agr. Exp. Sta. Tech. Bull. 37:413-591.
10. Smith, J. Warren. 1915. The effect of weather upon the yield of potatoes. Monthly Weather Review (U. S. Weather Bureau) 43.
11. U. S. Weather Bureau. 1950. Climatological Data, California 54.
12. Werner, H. O. 1934. The effect of controlled nitrogen supply with different temperatures and photoperiods upon the development of the potato plant. Nebr. Agr. Exp. Sta. Res. Bull. 75. 132 pp.

STORAGE OF POTATO SEEDS

F. J. Stevenson[1] and *W. C. Edmundson*[2]

Division of Fruit and Vegetable Crops and Diseases, Bureau of Plant Industry, Soils and Agricultural Engineering, Agricultural Research Administration, United States Department of Agriculture, Washington, D. C.

(Accepted for publication September 12, 1950)

Storage of potato seeds has little interest for the grower who plants tubers or pieces of tubers to produce a crop; but the subject is of primary importance to the geneticist and other scientists who are trying to solve some of the growers' problems by breeding improved varieties of potatoes. The growing of seedlings from true seed is a necessary step in the origination of new varieties. It is of especial interest at present, since plans are being made to collect and maintain varieties and species of the potato, together with all the important crops, so that the most valuable genetic characters may be readily available to plant breeders.

The potato germ plasm can be maintained in tubers or in true seed. Tubers must be grown every year but seed can be stored for a number of years. Clark[1] stored samples of a single lot of potato seed for 13 years under four different environments: in a heavy manila envelope at room temperature, ranging from 65° to 75° F. during the winter, and 85° to 90° or higher during the summer, and in tightly corked bottles at three temperatures: room, 40° and 32°.

The seed in the envelope at room temperature was the first to lose its viability. At the end of 6 years only about 4 per cent of this seed germinated. The seed in the bottle at room temperature remained viable longer. It showed about 13 per cent germination after 10 years, but none the thirteenth year. After 11 years the seed in the bottle at 40° F. showed 84 per cent germination, but about 40 per cent the twelfth and thirteenth years. At 32° the seed maintained its viability throughout the 13-year period, showing 87 per cent germination at the end of that time.

From 1912 to 1940 much of the surplus seed produced in the potato-breeding program of the United States Department of Agriculture was stored in coin envelopes at room temperatures. A study of the viability of this seed was made at the Plant Industry Station, Beltsville, Maryland, in the spring of 1950. Samples of seed produced each year from 1912 to 1940 were tested for germination, but only one sample (harvested in 1938) showed any signs of life, with only 30 per cent of the seed germinating. Since 1941 the surplus seed has been kept in coin envelopes in a refrigerator at approximately 34° F. Samples of seed harvested each year from 1941 to 1949 were planted May

[1] Principal geneticist; [2] Senior horticulturist.
[3] Clark, C. F. 1940. Longevity of Potato Seed. Amer. Potato Jour. 17:147-152.

26, 1950. Seventeen days later all these lots had germinated. The percentages of germination, based on two 100-seed samples of each, are given in table 1.

TABLE 1—*Germination percentages for lots of potato seed produced at Beltsville, Maryland, each year from 1941 to 1949, held in a refrigerator at approximately 34°F., and tested for viability in the spring of 1950.*

Year Grown	Germination (Mean of Two Samples)
	Per cent
1941	83
1942	72
1943	54
1944	87
1945	42
1946	53
1947	60
1948	86
1949	79

Some of the percentages of germination were not high, but the data in table 1 show that all the lots were viable. The 1941 lot that had been stored for 9 years gave 83 per cent germination. Two of the other lots were higher but the remaining six were lower. However, viability in any of them was sufficiently high to insure a crop of seedlings.

At Greeley, Colorado, crosses have been made in the greenhouse each year from 1936 to the present. The surplus seed has been stored in half-ounce screw-top bottles in the basement of the laboratory building. The storage room is relatively cool, although no effort is made to control the temperature.

In the fall of 1949 a germination test was made on representative lots of seed; two for each year from 1936 to 1948, inclusive. Five 100-seed samples of each lot were tested so that the percentage of germination for any one year is based on 1,000 seeds. The mean percentage of germination of each 1,000 seeds is given in table 2.

The data show a high perecntage of germination for all lots of seed, thus indicating that seed can be stored in screw-top bottles in a reasonably cool but variable temperature for at least 13 years. These same lots will be tested again at some future time. It has been known that the rate of germination of new seed is usually much slower than that of seed 1 year old or older; but in these tests some of the old seed required a much longer period for germination than was to be expected. Fifty per cent or more of the seedlings emerged in 16 to 20 days. After 40 days all plants were counted and removed from the seed flats, and it was thought that all viable seed had germinated; but seedlings continued to emerge from seed of all ages 50 days after plant-

TABLE 2—*Germination percentages for lots of potato seed produced in the greenhouse at Greeley, Colorado, from 1936 to 1948, inclusive, and stored in screw-top bottles in the basement of the laboratory building.*

Year Grown	Germination (Mean of 10 Samples)
	Per cent
1936	81
1937	78
1938	83
1939	81
1940	79
1941	79
1942	87
1943	61
1944	79
1945	79
1946	86
1947	87
1948	85

ing. In more than one-half of the lots a few seedlings appeared after that time. Sixty-five days after planting the test was discontinued and all late plants were counted and removed. It was observed that the plants that emerged late were less vigorous than those that emerged early.

Discussion and Summary

For many years the United States Department of Agriculture has maintained at Presque Isle, Maine, a collection of old and new varieties of potatoes, both domestic and foreign, and a number of the best-known wild species. The cultivated varieties have been grown every year from tubers; the species usually from seed. Virus infection is a constant threat to the growing crop, and in times past much valuable material has been lost because of it. Tubers relatively free from disease can be produced by growing the plants in an isolated place, spraying with DDT or Parathion to kill the insect vectors, roguing, and harvesting early. If there are any indications of virus infection the seed tubers should be tested by indexing. Maintenance of this collection by growing them from tubers over a period of years has involved much labor and expense.

If maintenance of a general reservoir of the germ plasm is the main objective it can be done with less effort and expense in true seed. The only labor involved is in the pollination work and many varieties and species produce seed by natural pollination. Particular combinations of genes might be lost but new combinations could always be produced.

Seed will remain viable for a period of years, the time depending to some extent on the storage conditions.

Tightly-stoppered bottles seem to preserve the viability longer than paper containers. Cold storage is helpful under climatic conditions that prevail at Beltsville, Maryland. It is not always necessary, as can be seen by the germination percentages of the seed produced and stored at Greeley, Colorado. High relative humidity or sudden changes in atmospheric conditions, such as often occur at Beltsville, are thought to be detrimental to the viability of seed. Storage of seed in a refrigerator or in tightly-stoppered bottles prevent the seed from being affected by these conditions. The relative humidity at Greeley, Colorado, is much lower than at Beltsville and not subject to such frequent changes; under such conditions it is evident that seed can be stored for many years in tight-stoppered bottles in a relatively cool room without controlled temperature.

SECTIONAL NOTES

North Dakota

North Dakota will harvest about three-fourths of the usual crop of certified seed potatoes this fall. The quality will be good, according to R. C. Hastings, state seed commissioner. The prolonged cold spring made most planting unusually late and the harvest a little later than normal this season. Although the digging of approximately 500 cars of early seed started August 20th, the major digging operations will not begin until about September 20th, and the storage, therefore, will not be completed until the middle of October. North Dakota is under its quota in acreage allotment set by the Department of Agriculture. This state is in the main a red potato-producing area. Since overplanting has not taken place in North Dakota and in some dry areas yields are low, it is expected that the potato crop will be below the estimate set by the Department of Agriculture. North Dakota is especially proud of the perfect start it has in the new Kennebec variety. Practically all the seed from this state is dry-land grown above the 47th parallel north. North Dakota has gained an enviable reputation in the south and in other areas demanding the best in seed stock. The certification tag of North Dakota is recognized as representing disease-free seed, seed of high vitality and seed which will, under reasonable conditions of soil and cultural methods, produce a maximum yield. In addition to increased yields, seed grown in this territory has been found to mature earlier, thus enabling the commercial grower to get his commercial potatoes on the market at an earlier date.—Grace Hudson.

Oregon

The marketing agreement committee of this area recommended to the secretary a 2″ minimum and a maturity clause providing that not more than 10 per cent show over 25 per cent leathering or skinning injury. This was approved by the secretary and is now in effect. All potatoes under 2″ are being diverted to stock feed.

Klamath Potato Growers' Association is continuing the marketing improvement program. Cooperative arrangement with dealers insures consumer-sized packages with smaller tolerance for defects and improved handling. There is considerable interest in this program which is financed through a tax on growers administered by the Oregon Potato Commission. This is a State act provided for improving the quality of Oregon potatoes.—C. A. Henderson.

South Dakota

Harvesting of a very excellent crop of potatoes is underway in South Dakota and at this writing (October 4) the crop is about one-half harvested. Most of the potatoes are going into storage. There is no activity in the certified seed trade, and the commercial market is too low to attract sellers.

All indications are that the South Dakota potato crop will be approximately 2,000,000 bushels, compared with 1,008,000 last year. The quality is very good with a low percentage of B size.

There will be no dumping of potatoes in South Dakota this fall. Live stock feeders are taking all the No. 2 stock and "B" size offered for sale. Twenty cars have gone to the school lunch program. The support price in October is 79 cents per hundred at the grower's gate. For the school lunch program the grower receives an additional 41 cents for services performed if the potatoes are in new sacks. When the potatoes are purchased by a feeder the grower gets 9 cents additional for inspection and loading. The feeder pays the P. and M. A. county office 8 cents per hundred, which includes 7 cents for loading and 1 cent for the potatoes. The C. C. C. pays the marketing agreement assessment of ½ cent per hundred. This comes from the 5-cent selling charge, which isn't allowed on C. C. C. purchases.

A total of 3,404 acres passed the first two field inspections this season, of which 1,935 acres were Bliss Triumphs; 424 acres Irish Cobblers; 729 Pontiac, and other varieties, 316 acres. Three cars of certified Triumphs were shipped to Cuba, but another certified stock is going into storage for shipment after January 1.—John Noonan.

PROGRAM OF THE ANNUAL MEETING OF THE POTATO ASSOCIATION OF AMERICA

December 1, 2, 3, 1950

Hotel Peabody

Memphis, Tennessee

Friday Afternoon, December 1, Hotel Peabody, Room 200, 1:30 P. M.

H. A. REILEY, *President, Presiding*

1. *Effect of Various Methods of Handling Seed Potatoes in Preparation for Planting* (10 min.) E. V. HARDENBURG, Cornell University, Ithaca, N. Y.
2. *Response of Potatoes to Rate and Placement of Nitrogen Tests in Connecticut, 1948-1950* (20 min.) ARTHUR HAWKINS, Storrs Agricultural Experiment Station, Storrs, Conn.
3. *Potato Fertilizer Experiments in Upstate New York* (15 min.) M. W. MEADOWS, Cornell University, Ithaca, N. Y.
4. *Effect of Rate of Fertilizer Application, Spacing of Rows and Irrigation on Yields of Potatoes* (20 min.) ORA SMITH, E. R. MARSHALL, J. R. ORSENIGO, J. E. KENNEDY and R. F. FOLEY (20 min.) Cornell University, Ithaca, N. Y.
5. *Extreme Case of Soil Toxicity to Potatoes on Formerly Productive Soils* (25 min.) ARTHUR HAWKINS, B. A. BROWN and E. J. RUBINS, Storrs Agricultural Experiment Station, Storrs, Conn.
6. *Chemical Weed Control in Potatoes* (10 min.) RICHARD J. ALDRICH and JOHN C. CAMPBELL, New Jersey Agricultural Experiment Station, New Brunswick, N. J.
7. *Controlling Weeds in Potatoes with Chemicals* (20 min.) ORA SMITH, E. R. MARSHALL, J. E. KENNEDY, J. R. ORSENIGO and R. F. FOLEY, Cornell University, Ithaca, N. Y.

Friday Evening, December 1, Hotel Peabody, Room 200, 7:30 P. M.

H. O. WERNER, *Presiding*

Smoker, social hour, discussion, movies, etc.

Report of Committee on Visual Education—GORDON A. BRANDES, *Chairman.*

Saturday Morning, December 2, Hotel Peabody, Room 200, 9:00 A. M.

H. A. REILEY, *Presiding*

Presidential Address, H. A. REILEY

Business Meeting

Report of Secretary

Report of Treasurer

Report of Editor, American Potato Journal
Report of Certification Committee
Report of Potato Introduction Committee
Report of Membership Committee
Report of Resolutions Committee
Report of Auditing Committee
Report of Honorary Membership Committee
New Business
Report of Nominating Committee
Election of Officers

Saturday Afternoon, December 2, Hotel Peabody, Room 200, 1:30 P. M.

J. W. SCANNELL, *Presiding*

1. *Field and Storage Application of Growth Substances to Potatoes* (15 min.) E. R. MARSHALL and ORA SMITH, Cornell University, Ithaca, N. Y.
2. *Some Factors Affecting Carbon Dioxide Absorption by Potato Leaves* (15 min.) H. W. CHAPMAN, Iowa State College, Ames, Iowa.
3. *Progress Report on the Response of Resistant Varieties of Potatoes to Irrigation* (15 min.) A. J. PRATT, Cornell University, Ithaca, N. Y.
4. *Mobile Potato Diggers for Outlying Trial Plots* (15 min.) H. O. WERNER and R. B. O'KEEFE, University of Nebraska, Lincoln, Nebr.
5. *A Study of Grading Potatoes for Mealiness and Its Effect on Retail Sales* (15 min.) W. S. GREIG and ORA SMITH, Cornell University, Ithaca, N. Y.
6. *Influence of Location on the Ascorbic Acid Content of the Irish Potato (Solanum tuberosum)* (15 min.) JOHN C. NOONAN, R. E. WEBB, RITA B. ATTAYA and JULIAN C. MILLER, Louisiana Agricultural Experiment Station, Baton Rouge, La.
7. *Improved Methods of Processing Potato Chips* (20 min.) ORA SMITH, Cornell University, Ithaca, N. Y.

Sunday Morning, December 3, Hotel Peabody, Room 200, 9:30 A. M.

R. D. PELKY, *Presiding*

1. *Method of Determining the Toughness of the Potato Skin* (15 min.) J. S. GREGORY, Colorado A. & M. College, Fort Collins, Colo.
2. *Clonal Variations in the Chippewa Potato Variety* (15 min.) G. H. RIEMAN, HENRY DARLING and MELVIN ROMINSKY, University of Wisconsin, Madison, Wis.
3. *The Control of Early and Late Blight of Potato in Ohio in 1950 by Various Old and New Fungicides* (15 min.) J. D. WILSON, Ohio Agricultural Experiment Station, Wooster, Ohio.
4. *Phloem Necrosis of Irish Potato Tubers in Washington* (15 min.) AVERY E. RICH and SETH B. LOCKE, State College of Washington, Pullman, Wash.
5. *Performance of Five Scab Resistant Varieties under Nebraska Conditions* (15 min.) ROGER F. SANDSTED and H. O. WERNER, University of Nebraska, Lincoln, Nebr.

6. *Some Factors Influencing Infection by Corynebacterium sepedonicum in Potato Plants* (20 min.) G. H. STARR, University of Wyoming, Laramie, Wyo.

7. *Some Observations on Effects of Wettable DDT and Emulsifiable DDT on Potato Quality and Blight Control* (15 min.) BAILEY B. PEPPER and JOHN C. CAMPBELL, New Jersey Agricultural Experiment Station, New Brunswick, N. J.

Sunday Afternoon, December 3, Hotel Peabody, Georgian Room. Joint Session with American Phytopathological Society, 1:30 P. M.

O. D. BURKE, *Presiding*

1. *Variation in Virulence of Potato Virus Y Isolates from Different Sources* (15 min.) R. H. LARSON and J. F. DARBY, University of Wisconsin, Madison, Wis.

2. *Indexing Potatoes for Virus X, Including the Use of Tuber Juice* (15 min.) W. G. HOYMAN, U.S.D.A., North Dakota Agricultural Experiment Station and North Dakota State Seed Department, Fargo, N. D.

3. *Inhibition of the Potato Scab Organism by Soluble Aluminum Ions* (12 min.) G. A. GRIES, Department of Botany and Plant Pathology, Purdue Agricultural Experiment Station, Lafayette, Ind.

4. *Field Control of Potato Scab in California* (15 min.) JOHN W. OSWALD and DAVID N. WRIGHT, University of California and Farm Advisor, Kern Co., Bakersfield, Calif.

5. *Potato Tuber Growth and Scab Infection* (15 min.) W. J. HOOKER and O. T. PAGE, Iowa State College, Ames, Iowa.

6. *Gradients of Potato Late Blight Observed around Artificially Inoculated Plants* (15 min.) P. E. WAGGONER, U.S.D.A.

7. *Studies on the Control of Golden Nematode (Heterodera rostochiensis)* Woll. *1923, with Systox Spray (E-1059) an Organic Phosphate Material* (15 min.) J. N. SASSER, J. FELDMESSER and G. FASSULIOTIS, U.S.D.A.

8. *Solanum xanthii and S. integrifolium, New Hosts of the Golden Nematode (Heterodera rostochiensis)* Woll. (7 min.) W. F. MAI, Cornell University, Ithaca, N. Y.

9. *Nematodes Found in New York State Potato Fields with Several Different Cropping Histories* (10 min.) B. F. LOWNSBERRY, J. W. LOWNSBERRY and W. F. MAI, Cornell University, Ithaca, N. Y.

10. *Studies in the Nutrition of Corynebacterium sepedonicum* (Spieck and Kotth.) Skapt. and Burkh. (15 min.) D. S. MacLACHLAN and F. S. THATCHER, Department of Agriculture, Ottawa, Canada.

11. *Eight Years of Dithane Versus Copper on Potatoes in Delaware* (15 min.) J. W. HEUBERGER, Delaware Agricultural Experiment Station, Newark, Del.